Touch sensitive display device

The invention relates to a touch sensitive display device with a multiple of picture elements and having means for applying driving voltages to said picture elements the display device.

The display device is for instance a liquid crystal display device. Liquid crystal display devices have found widespread use in the computer industry and in handheld devices ranging from mobile telephones and price tags to palm top computers and organizers. Also the combination with a touching device such as a stylus has found widespread applications, while also a need for ways of providing input via the display screen is felt.

USP 5,777,596 describes a touch sensitive liquid crystal display device that allows putting input into the associated device (e.g. a computer) by simply touching the display screen with a finger, a stylus or a pen. The device continuously compares the charge time of the liquid crystal display elements (picture elements) to a reference value and uses the result of the comparison to determine which elements are being touched.

One of the problems in said touch sensitive liquid crystal display device resides in restoring the right image after sensing. This is due to the fact that a blinking line is used which represents the switching of all picture elements in a row between two extreme states. When the blinking line reaches a certain row touching is detected by measuring the charging time of the picture elements. After measuring the picture elements are provided with adequate voltages to display the right image. In a similar way sensing by means of a blinking spot is disclosed in USP 5,777,596.

Such blinking however is visible on the display (artifacts)

Moreover, if a reflective display device is used, internal DC bias voltages may be present whereby charging differs for writing odd or even frames. In DC –driving methods (low power liquid crystal displays, electrophoretic displays) no inversion occurs so the method cannot be used at all there.

The problem of providing blinking signals can be overcome by making the spacing means (spacers) part of said means for monitoring the electrical characteristics of the picture elements. Said electrical characteristics may be capacitive, (non-linear) resistive or piezo-electric characteristics. However this will require structuring of e.g. the (non-linear)

resistor into spacers with similar heights to ensure that electrical contact is created when the display is pressed since locally thinner spacers may not be pressed at all. Such processing will be complex, and touch sensing will not always be efficient at all points on the display.

The invention has among others as its goal to overcome these objections.

To this end a touch sensitive display device according to the invention comprises a layer of touch sensitive material, the touch sensitive display device having means for monitoring the electrical characteristics of said layer of touch sensitive material and sensing a change in said electrical characteristics.

By incorporating a layer with pressure sensitive characteristics (e.g. non-linear resistivity such as may be realized by means of quantum tunneling composites or a piezoresistive layer) into the display structure, the display structure itself becomes intrinsically touch sensitive.

In this way the need for structured spacers is avoided, while the entire display area is touch sensitive, which increases the touch sensitivity and makes this touch sensitive display applicable for flexible and even wearable display applications.
Moreover when the pressure sensitive layer is sandwiched in between two optical films (retardation film, polarizer film, etc.) which are in front of the display cell or in between the display cell and one of these optical layers, deteriorating of the front of screen performance due to air-substrate interfaces in front of the device, which refract and reflect light is prevented.

These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter.

In the drawings:

Figure 1 schematically shows a touch sensitive (liquid crystal) display device,

Figures 2 shows a cross-sections of a part of a touch sensitive (liquid crystal) display device according to the invention, while

Figures 3 and 4 show the principle of determining the coordinates of touching a touch sensitive (liquid crystal) display device according to the invention, and

Figure 5 shows a further embodiment of a touch sensitive (liquid crystal) display device according to the invention.

The Figures are diagrammatic and not drawn to scale. Corresponding elements are generally denoted by the same reference numerals.

Figure 1 is an electric equivalent circuit diagram of a part of a touch sensitive display device 1 to which the invention is applicable. It comprises in one possible embodiment (one mode of driving, called the "passive mode") a matrix of picture elements 8 defined by the areas of crossings of row or selection electrodes 7 and column or data electrodes 6. The row electrodes are consecutively selected by means of a row driver 4, while the column electrodes are provided with data via a data register 5. To this end, incoming data 2 are first processed, if necessary, in a processor 3. Mutual synchronization between the row driver 4 and the data register 5 takes place via drive lines 9.

In another possible embodiment (another mode of driving, called the "active mode") signals from the row driver 4 select the picture electrodes via thin-film transistors (TFTs) 10 whose gate electrodes are electrically connected to the row electrodes 7 and the source electrodes are electrically connected to the column electrodes. The signal which is present at the column electrode 6 is transferred via the TFT to a picture electrode of a picture element 8 coupled to the drain electrode. The other picture electrodes are connected to, for example, one (or more) common counter electrode(s). In Figure 1 only one thin-film transistor (TFT) 10 has been drawn, simply as an example.

Figure 2 shows a cross-section of a part of a touch sensitive liquid crystal device having a bottom substrate 11 and an upper substrate 12 with a liquid crystal layer 13 between said substrates. The touch sensitive liquid crystal device has (not shown) picture electrodes on the bottom substrate 11 and on the other substrate 12. The display device in this example further comprises a polarizer 14, an analyzer 15, a backlight structure 18 and in this particular example a further optical layer 16 such as for instance a quarter lambda plate and a protective layer 17.

According to the invention a structure or layer 19 with pressure sensitive characteristics is provided, in this particular example between the bottom substrate 11 and the polarizer 14. The pressure sensitive structure or layer 19 in this example has pressure sensitive particles 22 together with spacer particles 21 between two transparent conducting layers 20 (e.g. indium tin oxide).

A suitable class of materials to be used for the pressure sensitive particles 22 is formed by Quantum Tunneling Composites (QTC). QTC is a polymer composite with conducting particles deposited in its structure. The conducting particles have dendrites. The particles are spaced apart and do not form a physical conduction path.

Tensile or compressive strain on the material however brings the particles close to each other. The space separation of the particles is reduced by the presence of the dendrites. At a certain loading point, the space separation of the particles becomes close enough to enable the electrons from one particle to jump to the other particle through the dendrites. However, the dendrites from two different particles are still not in contact with each other. The quantum tunneling act of the electrons leads to rapid resistivity decrease of the material as a whole. This nonlinear behavior gives rise to a transition point that sharply changes the resistance of the material from 10^{12} to 10^{-1} Ω.

Hence, QTC is a pressure/force sensitive switching material whose switching properties are comparable to these of a mechanical switch. Moreover it can be moulded into different shapes and can be mixed with other polymers.

Between the two transparent conducting layers 20 a mixture of normal polymer non-conducting spherical spacers 21 and pressure/force sensitive (QTC) spacers 22 is provided in this example. The normal polymer spacers 21 prevent the QTC spacers 22 from being overloaded and going to plasticity. Another function of the normal polymer spacer is to ensure that there is no shorting between the upper and lower layers 20. The diameter of the QTC spacer 22 preferably is less than or equal to the size of the normal polymer spacer 21.

On the other hand the sensitive layer can be a mixture of compressible bonding material, such as a silicone rubber mixed with conducting spherical spacers, having a diameter smaller than the thickness of the layer of compressible silicone rubber.

So in this example the structure or layer 19 becomes intrinsically touch sensitive. This is represented in Figure 3a, which is an electrical equivalent of the pressure sensitive structure or layer 19, by means of the variable resistor 23. Figures 3 and 4 show how the impedance between the upper and lower electrode is monitored.

When no pressure is applied the impedance between the upper and lower electrode is close to infinity, while V_{read} of a voltage source 25 is chosen close to zero, as shown in Figure 3a.

Upon touching the pressure sensitive structure or layer 19 a rapid drop in resistance indicates a touch action. The amount of pressure is determined by measuring the impedance of the pressure sensitive structure or layer 19. Said resistance is

$R_{QTC} = \frac{V_s - V_{read}}{V_{read}} R_{read}$ in which R_{read} is a readout resistor, indicated in Figure 3 by the resistor 26

The sensing system then may proceed to detect the x y co-ordinates by means of using one of the electrodes 20 as a probe. As shown in Figures 3b and 3c the voltage V_S is applied to the edges of an electrode 20, either directly or via mutually insulated low – impedance strips 24, such as metal strips. In one direction (y), if the picture element has a height H, the y – location is given by $y = \frac{V_T}{V_S} H$, in which V_T is the voltage of the QTC spacer layer upon touching. On the other hand $V_{read} = \frac{V_T R_{read}}{R_{QTC} + R_{ITO1}}$, leading to

$$y = \frac{V_{read}\left(R_{QTC} + R_{ITO1}\right)}{V_S R_{read}} H .$$

In a similar way, in the other direction (x), if the picture element has a width W the x – location is given by $x = \frac{V_{read}\left(R_{QTC} + R_{ITO1}\right)}{V_S R_{read}} W.$

The sensing system starts with a calibration step 31 (Figure 4) in which the values of V_S are calibrated (e.g. V_S (0, H) and V_S (W,0) together with V_S (0,0), the latter generally being ground. Then the sensing system, if necessary after being switched on (step 32) goes to the touch detect mode (step 33) The sensing system then may proceed to detect the x - y co-ordinates by means of using one of the electrodes 20 as a probe. Indication of a touch action is determined by measuring the amount of pressure (e.g. by measuring the impedance of the pressure sensitive structure or layer 19, Figure 3a). If a certain amount of pressure is present (a kind of threshold, which may be adjusted if necessary, step 34) the sensing system then may proceed to detect the x y co-ordinates by means of using the method Figures 3b and 3c (step 36) and then return to the touch detect mode (arrow 37). If a too small amount of pressure is present the sensing system immediately returns to the touch detect mode (arrow 35).

As shown in Figure 5 the pressure sensitive layer may also be present between two optical films (in this case a retardation film 16 and a polarizer 15,but other kinds of optical films, like mirror layers, reflective and transflective layers are possible too) in front of the display device. The pressure sensitive layer may also be present in between the substrate 13 of the display device and one of these optical layers. In this case no extra films are used in front of the display cell and the number of air-substrate interfaces, which refract and reflect light, in front of the screen is reduced.

The protective scope of the invention is not limited to the embodiments described, while the invention is also applicable to other display devices, for example,

emissive, electrochromic and electrowetting displays. On the other hand the normal polymer spacers 21 as shown in Figure 2 need not always be present.

Alternatively, flexible substrates (synthetic material) may be used (wearable displays, wearable electronics).

The invention resides in each and every novel characteristic feature and each and every combination of characteristic features. Reference numerals in the claims do not limit their protective scope. Use of the verb “to comprise” and its conjugations does not exclude the presence of elements other than those stated in the claims. Use of the article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.